AD NUMBER
AD841621
NEW LIMITATION CHANGE
TO Approved for public release, distribution unlimited
FROM Distribution authorized to U.S. Gov't. agencies and their contractors; Foreign Government Information; JUL 1968. Other requests shall be referred to Commanding Officer, Fort Detrick, Attn: SMUFD-AE-T, Frederick, MD 21701.
AUTHORITY
BDRL ltr, 13 Sep 1971

TRANSLATION NO. 1

DATE: July 1968

DDC AVAILABILITY NOTICE

This document is subject to special export controls and each transmittal to foreign governments or foreign nationals may be made only with prior approval of Commanding Officer, Fort Detrick, ATTN: SMUFD-AE-T, Frederick, Md. 21701.

DEPARTMENT OF THE ARMY
Fort Detrick
Frederick, Maryland

CONSTRUCTION ELEMENTS OF THE MODERN ~~GERMAN~~ VACUUM DRYING INDUSTRY

by Dr. of Engineering Heinz Haas, Renscheid-Lenner[1]
(translated from the German: VDI, Zeitschrift des vereines deutsches ingenieure, vol. 94, Number 13, Susseldorf, 1 May 1952)

---

[1]Abstract from a discourse delivered at the session of the labor commissions' "contstruction elements of apparatus manufacture" in Bad Kreusnach on the 25th and 26th of March, 1952.

THE PRACTICAL CONSIDERATION OF THE VIEWPOINTS OF THE DRYING INDUSTRY.— The practical consideration of the viewpoints of the drying industry lead to a cylindrical or rectangular housing form depending on the mode of operation of the vacuum dryer. Also the rectangular housing form is welded many times today and is provided with non rusting inner walls. In the case of turbine dryers the deposit and the packing box are carried out separately. Particular attention is devoted to the proportion of the heat transfer which occurs from the heating body to the material to be dried (the product) and to the housing as well as to the outer heating cover in order that corrosion due to condensation of the liquid may be avoided.

THE APPROPRIATE HOUSING FORM.—From an evacuated container due to the outside pressure of one atmosphere on each square meter of surface of the wall of the container a gravity of ten tons must exist at the surface of the container walls;so that they are not crushed in by the great pressure, they must either be very thick or correspondingly strengthened. Cylindrical evacuated containers are capable of resistance of a remarkable outside pressure so that in proportion a smaller wall thickness is needed and additional supports can be neglected. From the standpoint of the constructers it is seen from this that cylindrical vessels with arched doors, covers and floors are to be preferred as vacuum apparatuses.

Such a cylindrical housing form already exists in the case of the vacuum turbine dryer in which the self turning blade mechanism inorder to be entirely effective requires a cylindrical cover just as also in the case of the vacuum drum dryer in which the housing form turns itself on its own axis. With the vacuum plate dryer the steam heated tray on the bases of the reverberatory mechanism describes a ring-target shape. The cylindrical housing form is adapted appropriately to this plate form. It is clear that for all these drying apparatuses the cylindrical housing form was applied in the beginning of the field and also still prevails today.

For the vacuum drying chamber, the vacuum one and two-roller dryer, the vacuum spray tunnel dryer, the cylindrical housing form does not result in itself from the manner of operation of the installation. The first vacuum drying chambers which

had been assembled by Emil Passburg in Russia for the drying of sugar loaves in regard to the simple production also possessed a cylindrical housing form. To be sure these were suitable on the basis of stability and production, cylindrical evacuation chambers now have from the standpoint of the drying industry anumber of essential disadvantages which have led to the use of more and more rectangular vacuum drying chambers. Figures 1 shows a vacuum drying chamber with a cylindrical houding form and figure 2 a drying chamber with an equal loading surface which is placed in a rectangular housing form. O ne sees immediately that the cylindrical drying chamber has above and below as well as laterally from the heading plate pile a large dead space which in the different sizes of dryers makes up 56- 110% of the volume of the rectangular construction. The required floor space of the cylindrical chamber in relation to the highth and width is 10- 50% larger. Also in front of and behind the drying chamber a condiderably larger free space from the circular door of the cylindrical chamber is necessary than in front of the door of the rectangular chamber of equal capacity. The vacuum pump which is necessary to evacuate the vacuum dyyer determines now first of all not by the vapor concentration which is produced in a unit of time and also not the concentration of the outside air which presses in through outside leakage but through the time in which the desired vacuum in which the substance to be dried is capableof being produced. The sensitive produce whcih is to be dried which would undergo damage if a critical temperature were obtained is placed in the drying tray, which is warmed previously by means of steam or by some fuel in the hot plate. Thus the arrangement must be prepared very rapidly and be evacuated to a residual pressure in order that the product does not assume this critical temperature. The residual pressure must be less than the saturated vapor pressure at the critical temperature of the product which is being dried. One therefore adjusts the vacuum pump for the sensitive material to be dried in such a way that the desired vacuum is obtained within 5 minutes after the starting of the pump. With less sensitive products one can extend the duration of the evacuation to ten minutes. With cylindrical drying chambers with their greater volume compared to rectangular drying chambers of equal drying capacity there are therefore correspondingly larger vacuum pumps, thatis to say higher prime costs, larger required floor space and owing to the greater power required, the cost of operation necessarily runs higher.

Since the vacuum drying is not an evaporation process but rather a vaporisation process, the vapor consists almost exclusively of steam. Everywhere there, where it could be cooled below its saturation temperature, a condensation occurs as a result. The vapor contains corrosive substances therefore condensation allows the formation of ions and thereby promotes corrosion. Such a condensation can not occur on the hot plate itself since it has a higher temperature than the vapor but probably does occur on the housing wall if they are not supplied with sufficient heat essentially by means of heat conduction or radiation from the hot plate so that their temperature lies above the temperature of condensation of the vapor in spite of the heat loss to the outside.

A glance at figure 1 shows clearly now thatthe heat through conduction

from conduction from the hot plate above the support of the cylindrical cover of the vacuum drier is carried only to eight areas. In the case of rectangular drying chambers in which the individual iron supports on which the hot plate rests are welded directly to the wall of the housing, the heat, as opposed to that in the cylindrical dryers can be conducted to a great many connecting places. Also relative to the heat transfer by radiation it is found that the cylindrical chambers owing to the greater mean interval of the housing wall from the hot plate ~~is~~ is less than that in the rectangular chamber. It is therefore a general disadvantage of these kinds of cylindrical chambers that a condensing sump is usually formed on the plate floor during the drying which influences unfavorable the drying process and in the presence of corrosive vapors leads to an undesirable corrosion phenomenon. This condensation can be avoided if one incloses the housing outside with a heating coil and then further suitably insulates it. With the rectangular chamber, which in itself is already slightly prone to condensation, ~~which~~ one is therefore, in the case of german and American designs (modern) converted into developing the covers and plate floors of the drying chambers equal to the hot plate. Thus the side walls form with their upper and lower parts synchronous to the sidewalls of the heating plate so that in addition a heat transfer by conduction occurs.

These statements indicate that from the standpoint of the drying industry a rectangular vacuum drying chamber with the reinforcement which depends on its shape of design is preferred unconditionally as opposed to the cylindrical vacuum drying chamber, especially for what it offers the designer.

For the vacuum-roller dryer the dead space is generally without influence on the drying process. Since this dryer works largely continuously one begins often with the insertion of the product if the desired vacuum is to be obtained. For the one roller dryer the cylindrical housing is preferred in adaptation to its turning cylindrical roller. In the case of the two rollerdryer, to be sure, the cylindrical housing also predominated but one also encounters the rectangular housing especially for small designs. Since in this style of dryer the heat is transferred essentially by radiation fromthe rollers to the walls of the housing the condensation can be avoided only by the outside heating of the housing.

For the vacuum-shaking plate dryer which owing to its good automatic discharge in cases where the material is gummy as for example with nylon cuttings, has come into use as opposed to the vacuum drum dryer. The cylindrical design is used throughout since in this type, also from the viewpoint of the drying industry, there is no disadvantage as opposed to the rectangular form. In both cases one would load only 1/3 of the toatalvolume so that in both types the empty spaces to be evacuated are equal.

Also with the spray tunnel dryer which likewise works continuously the cylindrical housing design has no disadvantage in industrial drying; here also the condensation must be prevented by outside

heating.

With this shourt insight into the appropriate housing form of the different types of vacuum dryers the particular kind of dryer is to be indicated by special construction elements.

WALL MATERIALS AND MAINTENACE IN THE DRYING CHAMBERS.-- Formerely the rectangular housing was frequently made of cast iron since the production of such housings with sheet iron caused diffaculties with the necessary reinforcement. The more that welding found acceptance in apparatus construction the more men converted to welded steel husing. In favor of the cast housing to be sure was the somewhat greater corrosion resisting quality of the cast iron as opposed to the steel. But it is possible today in welded steel cabinets to avoid all condensation (the real prerequisite for rust) so that this advantage of the cast housing is unessential. Welded steel vacuum drying chambers which were loaded with acidiferous die pulp have worked satisfactorily over a ten year period whereas the tubing connected to these cabinets which were not protected from condensation had to be replaced every few years. This clearly shows how important it is to construct the chamber in such a manner that all parts are sufficiently heated so that all condensation is avoided.

In the cousse of the year there is formed on the iron of the hot plate and on the cabinet housing a thin oxidation film from which a part can be scraped from the insertion of the drying tray in a careless manner, which then falls into the tray of the obtained product. Consequently, in the case of chambers for high quality material which are sensitive to that kind of trace of foreign bodies (as pharmaceutical products, for example penicillin, silver salts for the photoindustry, pure white pigments, bleaching agents) one changed over therefore to manufacturing the inner walls partley or completely of stainless steel. Figure 3 shows one such modern drying chamber which consists completely on the inside of stainless steel. Also the metallization of the inner parts has resulted in a good protection from rust.

The thickness of the layer in which one subjects the product to the drying process influences the time of drying in the first to second power according to American infestigations. With materials to be dried which are wet and good conductors of heat it can thus be calculated that the drying time will increase in direct proportion to the thickness of the layer; with dry substances which are poor heat conductors the time increases as the square of the thickness. On the average, with thicker layers of the product, a smaller drying capacity of the installation is obtained although there is less manual labor involved per unit of production. In general the installation is calculated for a a thickness of the layer of 10 mm.

THE SEATING AND CORRUGATED SUPPORTING IN TURBINE DRYERS.-- With the vacuum turbine dryers the performance of the self turning blade supporting tubes have always caused difficulties through the front walls during short periods of operation. This drying

apparatus which, in itself, is completely suitable for vacuum drying has accordingly not found the distribution which actually is due it. In the early designs the seating of the turbine supporting shaft combined with the packing box. Thereby a proportionately complicated system is obtained completely irrespective of the precautionary measures which always must be provided; therefore care was taken that no oil from the seating reached the product. In modern designs the seating and the packing box are accordingly as is shown in figure 4 separated from each other. A disadvantage of this design, to be sure, is that the seating interval which is somewhat larger, compared to early designs, where-by a higher bending (flexural) stress of the blade supporting tubes is obtained. This disadvantage, however, is more than compensated for by the suitable and clearly arranged construction. Just how far the replacement of the packing box through slip-ring seals will bring further advantage, the future must demonstrate.

HEATING ELEMENTS AND PLATE SPACING FOR THE DRYING CHAMBER.--
In regard to the heating of different vacuum installations there are also several questions which are of real significance for the designer and for the drying technician. For the vacuum drying chamber one can use for the heating on the one hand heating plates and on the other hand heating grates. Also if each producer of that kind of vacuum installation attempts to shape the surface of the heating plate as flat as possible as the floor plate of the drying plate, one must obtain in practice frequently only a moderately flat but multipoint contact. On the other hand if one uses a heating grate then a linear but single point contact appears. It is therefore understandable that the heat transfer in respect to a heating grate with an equal temperature gradient is smaller than that of a heating plate. Architecturally the heating grate is however more convenient for pressures higher than 5 or more atmospheric excess pressures since the heating plate then would have a wall thickness which would make it extremely heavy. Thus the thickness ofthe walls which would be necessary would amount to for example 5 mm. with 2-3 atmospheric excess pressures, 6-7 mm. with 5 a.e.p. and 10 mm with 10 a.e.p. One should now assume that ~~the grate has~~ with grate heating individual areas would dry differentially and indeed in such a way that the material nearly over the heating tube would dry faster in comparison and that over the interspaces would dry more slowly. However, as long as the material is still fluid the steam bubbles which were generated in the drying mix thoroughly the material so that a differential heating is not to be expected. The material becomes viscous so that equallizing currents can no longer exist and at the time of drying of the material there still prevails a relatively favorable heat transfer coefficient so that temporarily the danger of a differential drying exists. When the material becomes dry and thus the heat transfer at the time of drying ofthe material becomes very small then a heat equalization by means of conduction within the drying tray occurs and the danger of a differential drying is again stopped. Practical studies with heating grates have confirmed this.

A further significant question is that of selecting the plate interval. First of all it is determined by the material which is

to be dried. It tends to foam, that is, it passes through a viscous p~~h~~ase so that one selects in general a large interval. In other respects one limits the interval to the extent that with a given heighth of the drying tray a satisfactory insertion of the trays is s~~t~~till allowed. In order to utilize the heat of radiation of the upper tray one should select an interval not larger than is necessary according to the reasons just given. The data on the portion of radiation in the transfer of heat are very different; in Germany it is calculated as 20-25%, in the United States of America as 50%. Table 1 shows the radiation portion as dependent on the heat transfer coefficient, k, at the time of contact of the product in the case of warm water- and steam-heating of the plates. As is to be assumed the portion of the heat which is transferred by radiation falls as the coefficient of heat transfer, k, increases and, indeed, in the case of steam heating from 48% when k = 5 k cal/m^2h^oC (thus an already rather dry substance) to 13.7% when k = 30 k cal/m^2h^oC (thus a rather damp material). It is further found that the radiation portion increases as the temparature of the fuel increases (warm water- , steam- heat). Table 2 shows that the portion of radiation increases as the ~~tray~~ tray interval increases and indeed this is somewhat more with bigger trays than with smaller trays. If the trays were infinitely large and a uniformly high vacuum prevailed in the dryer then the interval of the trays would be practically without effect of the heat radiation. The smaller the trays become the more heat of the upper tray goes by the product and is radiated to the side walls. As the earlier statements show this heat loss by radiation is entirely to be desired, however, since it introduces to the cabinet housing the heat necessary for the prevention of condensation.

In the case of turbine dryers, especially with high vapor pressures, the question is raised whether a double cover heating or a heating by external pipe coils, which are welded on, are convenient. In the case of the double cover, the thickness of the inner cover must amount to, for example in a dryer of known size, 16 mm with 2 atmospheric excess pressures but 24 mm already at 6 a.e.p. In tube heating the thickness of the cover is determined only by the outside pressure of 1 atmospheric excess pressure. The cover is supported so well by the welded tubes that it can be kept relatively thin. On the other hand the coefficients of heat transfer, k, are, in the case of heating by pipe coils, somewhat smaller than with the double cover heating. Table 3 shows these kinds of values which were calculated on the basis of American supports and the values which were measured in practice in similar installations agree very well with them. It is clear that with the decreasing moisture content in the product the differences in the k-values disappear more and more since it then is controlled to a great degree by the coefficient of heat transfer of the time of the material to be dried. A disadvantage of the heating by pipe coils lies in the fact that a large welding is necessary for the carrying out of this part; the values in table 3 hold true for tubes with two continuous welding seams.

Table 1. Portion of radiation in the total heat transfer for cristolline materials to be dried.

Heat transfer coefficient k kcal/m^2 h $^\circ$C	Radiation portion in % in the case of	
	Warmwater heating (95° C)	Steamheating (2 a.e.p.)
5	43	48
15	20	23.5
30	12	13.7

Table 2. Influence of tray size and tray interval on the portion of radiation for steamheating with a heat transfer coefficient of k = 5

tray size m · m	portion of radiation in % in the case of a tray interval of		
	150 mm	100 mm	50 mm
1 · 1	48	50.4	51.8
1.5 · 1	50	52.5	54

Table 3. Coefficients of heat transfer k in the cover of vacumm turbine dryers

KIND of material handled	K IN KCAL/m^2h°C with		decline of output in % through tube heating
	double-saver heating	tube heating	
boiling solution	1320	900	32
agitated solution	870	710	18.5
viscous substance	580	485	16.5
lumpy mass	320	290	9.5
starch of 40% at 20% humidity	58	56.5	2.5

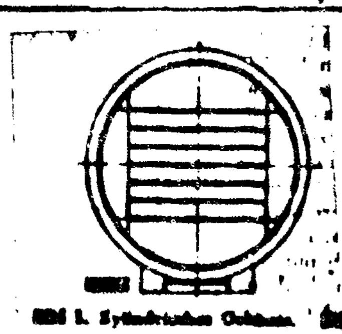

Fig. 1 Cylindrical housing

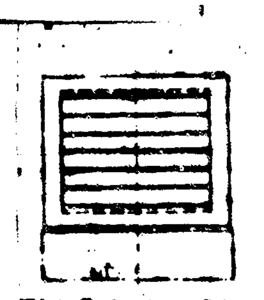

Fig. 2. Rectangular housing

Figs. 1 and 2. Vacuum- drying chambers with equal feeding boxes and different housing forms.